

# Spatial Database Management and Generation of VRML Models

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## Introduction

Staff in the Faculty of the Built Environment at the University of the West of England (UWE) have been involved in the 3D modelling of buildings and urban areas since 1984. These models have been used for applications ranging from the automatic co-generation of visualisation, drawings and schedules to Virtual Reality (VR) and the Web. Since 1984 a number of different Computer Aided Architectural Design (CAAD) systems have been used to create these models, some in succession to others, some in parallel with translation from one to another because each is easier to use in one sphere of the whole task than another. This need to successively pass the task in hand from one CAAD package to another is a strong endorsement of open standard non-proprietary description of data. These experiences also reinforce the view that in practice heterogeneous part-models with abstract mappings linking their various parts can be achieved pragmatically, whereas the seamless single building product model remains an elusive holy grail.[1]

Such heterogeneous models may be created independently, even to different scales and standards, however this is sufficiently difficult to manage in practice to justify a common underlying co-ordinating geometric structure or primary model to which all relate or from which all are initially generated.[2][3] Staff at UWE have been exploring the use of an underlying spatial database in which this primary model may be held. The visible and interactively explorable aspects of the model are output in Virtual Reality Modelling Language (VRML) that is browsable using plugins on the Web. The term spatial database or Spatial Information System (SIS) is used here as more inclusive of different domains than the conventional view of GIS, although commercial GIS may satisfactorily serve this and many similar functions. While fully 3D spatial analytical tools in GIS would be desirable, and the widely available GIS packages are still presented as two-dimensional and map-based, 3D data can be usefully stored and searched within them. This paper suggests an approach to shared group data entry, management and generation of appropriate levels of detail models from a single overall spatial database.

## The Context

The cost of keeping CAAD based large area urban models up to date and in continued use justifies a reappraisal of the breadth of applications and a broadening of access. Broader access requires lower access costs for group interaction and updating with eased distribution such as that offered by the Web. Hence UWE has moved from CAAD based modelling by a small group holding substantial expertise to the creation and use of shared models by larger groups without specific CAAD expertise. In seeking to meet broader demands and a less predictable and longer term range of uses both graphical and non-graphical information is held in the database and linked to VRML and Web output. Hence the models are both visualisable and form a co-ordinating spatial framework linking to associated images and non-graphical data.

## Modelling for Planning Visualisation

In 1995 UWE received a commission to model part of Bristol to create a VR experience to demonstrate the millennium proposals to the Commissioners, in conjunction with Bristol 2000, Bristol City, Division Ltd. and Aardman Animations. The models that resulted were considered to be at the lowest level of detail to acceptably convey a visual sense of presence to interactive VR users. However they were still too large area and too complex to achieve an acceptable frame rate then on Division's own state of the art VR equipment. The commissioners were shown video created from a



Tower of London CAAD Model

renderfarm approach using 3D Studio instead. Two models were created, one representing the existing area and one as proposed.[4] Both models have since been developed and applied in parallel but different ways by Bristol City and UWE respectively. The models were based on a combination of UK Ordnance Survey 1:1250 scale 2D map data with 1:10,000 scale 3D contour data, other data procured by Bristol City such as 3D street survey data and drawings submitted for planning approval, and bespoke photographic surveys. The available map data comprises polygonal building outlines measured at ground level and substantial additional elevational and roof morphological data from diverse sources is required to produce or maintain an effective 3D model. It became swiftly apparent that continued management of the model to keep it up to date as an accurate reflection of changes on the ground was a major data management problem. Piecing in new CAAD models received from Architectural Practices to visualise them in context as part of the planning negotiation process has often taken staff at Bristol City several days of work for each instance. Because the model is so complex and so proprietary the Bristol City staff operate in effect as a specialist visualisation bureau service.

Historic Royal Palaces (HRP) manage the Tower of London and are responsible for all aspects from conservation and maintenance management to the visitor experience. HRP have used for several years an Oracle based abstract building maintenance management system which then lacked links to drawings. UWE undertook some research with them to evaluate the use of a GIS to create the links between this data and their digital survey drawings. There followed in 1996 a commission to model the environs of the Tower of London to create illustrative material to support bids for funding to the Heritage Lottery Commission. The model was to provide the context for judging the visual impact of each stage of the increasingly detailed development and refinement of the designs. Two models were created, an as proposed and an as existing model. Both models were highly detailed. All structures, hard landscape and trees were modelled in 3D down to street furniture, railings and kerbs. These models were used to generate video from a renderfarm, and very high-resolution still images for presentation material. Both models were based on highly detailed 2D survey drawings of all the buildings and landscape procured by HRP. Other bespoke 3D, photographic and video surveys were obtained. The digital photographic survey alone occupied 6 CD Roms with each image stored at a resolution of 2048 by 1536 pixels. The more distantly viewed background data was extracted from Ordnance Survey 1:1250 scale maps and from a photogrammetric 'Cities Revealed' dataset from GeoInformation Ltd. Drawing detail was automated, turned into 3D and managed within Autocad, images were reconciled within Photoshop and both translated into 3DS Max for visualisation. The team task of creating these models was made particularly difficult by the limitations of the survey drawings and by the difficulties of searching for and retrieving and

correlating data from the wide variety of available sources. [5] In many ways these heterogeneous sets of linked information resemble those which prevail during the design and communication of a major new building project. Russell et al. describe a similar approach to hyperlinked architectural drawings.[6] Haas called for more specific identification of building levels and elements such as beams and columns in describing the STEP AP225 for exchange of 3D Building Models.[7] However a looser, more heterogeneous association between representative geometry and associated data may encompass both terrain, existing surveyed structures and new building elements. In fact experience at UWE indicates that while euclidean primitive solids are generally used as the basis for geometric description of CAAD based building models, these are less appropriate for either terrain or the irregularities of existing building structures based on measured surveys. In these cases the Triangulated Irregular Network (TIN) describes these surfaces better, the basis of the 3D studio based models. Superior interactive tools for remodelling such terrain surfaces were described in 'Virtual Terrain - a procedural bulldozer' by Erwin and Westart.[8] TIN's can however create bloated files in VRML if used indiscriminately. Recent work has therefore centred on NURBS (non-uniform rational B-splines) for which extensions to the Cortona VRML browser have been promised.[9]

### **Research Agenda**

A further goal of joint research between HRP and FBE/UWE was to develop more effective approaches to historic building maintenance management, visitor management and interpretation of historic sites to visitors. These desired outcomes entailed a closer and more interactive relationship between the model and other graphical and non-graphical data. In addition a wide range of archaeological data was examined with the intention of later modelling the various historic developments of the site. This included borehole data to enable reconstruction of the successive ground levels, with archaeological records from digs from which the existence and form of demolished or altered buildings could be projected. Data conversion and amalgamation from all the diverse sources was the major impediment to effective group working to create the models. It became apparent that retrieving all the appropriate data that described the part of the model under creation would be assisted by a spatial information system (SIS). Such a system could also provide a robust audit trail from the source data to the model, and vice-versa, an important consideration when attempting to model an historic site.[10] The two models, existing and proposed, shared many common elements and were in effect two different part models with a common core. Each model comprised approximately 100 Mbytes of geometry with 300 Mbytes plus of bitmaps. Management of two such linked models and their associated elements in Autocad and 3DS Max proved difficult with the available CAAD tools. It was therefore possible to predict that management of many more historic part models stepping back through time and allowing also for models of different expert interpretations derived from the same archaeological data to co-exist would be in itself a major task requiring a spatial database. It was also concluded that use of such an SIS to locate and manage all the various data sources and images including drawings would enhance the capacity of the text based Oracle management system. A specification for just such a heritage site management information system was drawn up in conjunction with the then Surveyor of the Fabric to HRP and has guided subsequent work.

### **GIS based retrieval of data for 3D Visualisation and Modelling**

The Tower of London modelling process pinpointed the desirability of a spatial database to manage the data available from which to model. VRML models in particular and VR in general lack the animated behaviour of crowd scenes, traffic and plant movement which give life and credibility to urban areas. It is possible to introduce some of these effects through integration of digital video into the scenes but this further raises the question of when to model and when drawing or map, film or image alone may suffice. This paper also questions whether it is essential to model at a consistent level of detail. A multimedia application may provide a credible sense of presence without additional 3D modelling in the CAD sense as evidenced by

the extensive use of panoramic images to convey urban experiences on the Web. Experience also shows that increasingly complex web-sites require an underpinning database management system to manage pages and links based on metadata such as author and expiry date. This trend is now being reversed with the increasing use of active server pages generated on demand from databases. A variety of multimedia outputs are becoming available on demand as bespoke pages. By the addition of locational data the underpinning database may become a spatial information system.

One means of reducing the total cost of use of such models is to broaden their appeal and thus spread the cost of initial creation and subsequent amendment and use across a wider range of applications and participants. Mitchell defined designing a building or development as fundamentally a collaborative, interdisciplinary, geographically distributed multimedia activity.[11] If this collaborative digital multimedia activity is integrated and disseminated on-line, and encompasses a large enough urban area, it may provide the context and constraints for future development and serve to inform and engage the public. In the UK it will be mandatory that all local planning authorities make much of this data available on-line within the next two or three years. Smith argues for a broader 'VR across the Web' based involvement in this activity so that it 'should be both usable and attractive to the public, the planner, the private sector and the political representatives involved in the planning process. A system should offer collaborative group interaction, with groups deciding and acting together to plan an environment for the good of the whole'. [12] These considerations led FBE/UWE to start afresh from the

original source data, to explore the use of a collaborative spatial database based approach within which to integrate models and interventions from various sources and from which to generate an overall navigable interactive whole. A succession of beta versions of a 3D VRML generator called Pavan have been used based on the Mapinfo 2D GIS, in collaborative feedback to the software author. (Since this work commenced ESRI have also introduced a more limited 3D model generation process from the Arcview 2D GIS). The 2D plan source data from which both the Bristol Harbourside and Tower of London models were generated have been re-entered into Mapinfo. The heights of each building element and roof morphology have been

coded onto the polygonal building outlines and associated with bitmap elevational detail. It has been found in practice that the resulting VRML model accords closely with the majority of the building modelling in the previous CAAD based models including complex battlements and crenellations. These models are however still based on proprietary source data because of which the current lack of security across the Internet precludes publication on the Web. There are exceptions where particularly complex forms such as ogee roof forms or deep relief have not been capable of satisfactory automatic generation from 2D plan forms or swept profiles. In these instances the specific complex element has been exported as VRML from CAAD and referenced as an external in-line file within the generated VRML model. This technique is also used for repetitive geometric 'library' elements such as street furniture and trees that can be instanced. These library elements can be reproduced complete with pre-scripted dynamic behaviours such as rotation of the sails on a windmill. VRML from any external source can be integrated in this way. High level of detail modelling can thus be viewed within a setting modelled at various lower levels of detail. The CASA research centre at Bath University initially defined a consistent



Tower of London in VRML from GIS

high level of detail for the whole of the Bath City model and now generates reduced level of detail part models from it. This creates difficulties in translation to lower levels of detail which in the longer term may be overcome by use of a NURBS based approach as is now in use in modelling for computer games.[13] An alternative and less resource intensive approach may be to model the whole at a lower level of detail and then to introduce pockets of higher detail as these become available from CAAD modelling or as debate and interactive use define a demand for more detail at that location. This would accord with the view that modelling and updating take place over a long period and that software, bandwidth, standards and detail will change over that time, rendering any fixed level of detail potentially obsolete.

### **Collaborative Modelling**

In two successive years groups of students drawn from a wide range of built environment disciplines from Geography to Surveying, without specific CAAD experience, have been engaged in collaboratively modelling one campus at UWE over the course of two or three hours per week in one semester. The available source survey data was divided out. Each student pair recorded the appropriate additional data and used digital cameras to acquire bitmaps. Each pair then modelled part of the buildings and terrain using Pavan and Mapinfo. The resulting jigsaw has then been re-assembled and a complete VRML model generated. It has indicated that it is practicable for a group working asynchronously to collaborate in creating and maintaining a large area urban model and that significant CAAD expertise is not required. (The students have also learnt many of the issues of CAAD management.) Roberts has described new site planning and design using VRML.[14] It may be argued that asynchronous group activity is increasingly necessary in both the collaborative virtual design studio and for timely planning information systems.

### **Levels of Detail of Associated Information**

A useful analogy for the relationship of associated information to models is that of the distinction between physical relief maps and political maps. The political boundaries generally change more frequently than the rivers, mountain ranges and other natural borders in the relief map. The two are associated in conventional GIS using what has often been described as a 'cookie cutting' process. The physical map is used as a background overlaid with thematic layers of points of interest and polygonal boundaries that are used to apportion it. In the VRML 3D model access to information can be made appropriate to the equivalent of the 'map-scale' at which the model is viewed through the use of a hierarchy of levels of detail. This is done by associating information with an abstract normally invisible boundary representing the cookie cutter rather than with the representation of the physical elements of the model. Thus at a distance equivalent to a scale of 1:1000 from the Tower of London it is named as a place in the context of other streets and placenames. At 1:1250 information can be invoked about the names, addresses and occupancy of its over fifty constituent buildings. At a distance equivalent to say 1:100, at which a single building or small group fills the display, information is triggered about the constituent zones of each building and the components such as windows, doors and materials from which each is composed. Yet much of the available planning brief information from Bristol City and similar sources has proved in practice to be associated loosely with localities or fuzzy regions rather than precise geometric limits. In this respect the model can readily serve as an electronic 'Yellow Pages' street directory, but more work is needed to define both how best to associate other information with specific levels of detail and viewer distance and viewpoint, how to make it easy to understand and access,[15] and how to provide effective access to the underlying database through the medium of the VRML model.

### **Tighter Integration of Spatial Database and VRML Model**

Currently changes to the VRML model are made by publishing the whole or any part of the model from the spatial database in the GIS. Each complete model of approximately 10 Mbytes of



VRML including terrain (less than 10% the size of the previous CAAD models) takes almost two minutes to publish on a typical 350mhz Pentium PC. Amendment of any part such as a change of elevational bitmap detail or plan form or output of one part of the whole can be regenerated in less than one minute. Hence the GIS based VRML model can be used to swiftly review the outcome of changes to a major urban area, generate a sequence of part-models or compare alternative proposals in context side by side in a frameset. The process is fast enough to compare favourably with the time taken to initiate similar visual modelling review of complex models within 3DS Max on more powerful PCs. In this respect a VR review function is also an important adjunct to discovering flaws during the creation of a complex CAAD model. Therefore current exploration of the combination of event driven behaviours and Structured Query Language is seeking to define how appropriately to modify objects in the VRML model on demand. This will enable the results of the spatial database search and analysis tools within the GIS database to be displayed interactively within the VRML representation. Queries such as 'where is...?', 'where is the nearest...?', 'what is near to this point...?', 'what has changed?' or 'what are the consequences of a proposed change?' may be demonstrated both visually and also by associated in frame on-demand web pages of abstract data. Similarly sensors within the VRML world may be used to instigate a search and output from the database. This is beginning to realise the potential for use of this process for asynchronous group modelling or updating along the lines of the collaborative virtual design studio and planning information system defined by Smith.

## Conclusion

Large area urban models will probably in time consist of different parts created independently and to different scales and standards. This will permit collaborative groups to share in the cost of developing and maintaining them without being limited to a single defining standard. However a common underlying co-ordinating geometric structure or primary model to which all relate is likely to emanate from the lowest level of detail at which data can be captured without extensive reinterpretation. In this respect much more locational data requires to be captured with visual images and information than is currently the norm. VRML is a useful de facto standard for defining and interacting with such models although the ISO standard VRML has yet to support the seamless simplification of geometric detail into the distance that NURBS now offers. VRML models based on spatial databases have the potential to become actively served with appropriate associated detail and data on demand.

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